Please return to Instrument Pool Room
when not required

571 & 572
INSTRUMENT POOL
LIBRARY
IH 28317

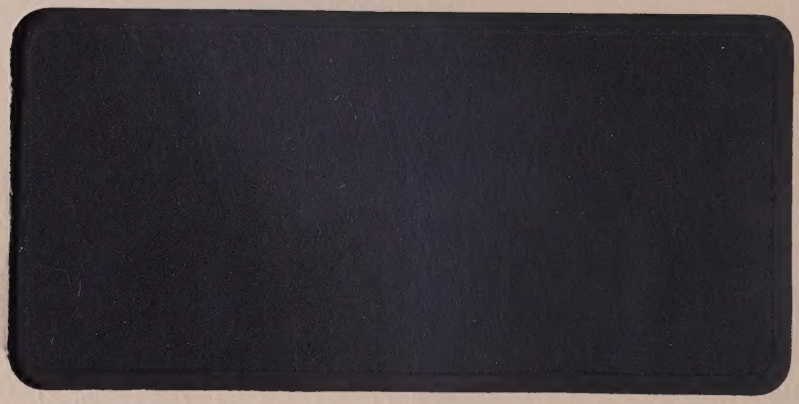
MODEL 600

MULTI-PURPOSE ELECTROMETER

AND ACCESSORIES

INSTRUCTION MANUAL

KEITHLEY INSTRUMENTS, INC.
CLEVELAND, OHIO



571 & 572
INSTRUMENT POOL
LIBRARY
IH 2C-224

MODEL 500

MULTI-PURPOSE ELECTROMETER

AND ACCESSORIES

INSTRUCTION MANUAL

KEITHLEY INSTRUMENTS, INC.

CLEVELAND, OHIO

THANK YOU AGAIN

INSTRUMENT POOL
LIBRARY

CONTENTS

	SECTION
INTRODUCTION	I
SPECIFICATIONS AND DESCRIPTION	II
CIRCUIT DISCUSSION	III
A. Voltmeter	
B. Ammeter	
(1) Normal	
(2) Fast	
C. Ohmmeter	
(1) Normal	
(2) Guarded	
(3) External Voltage	
OPERATION	IV
A. Preliminary Steps	
B. Voltmeter	
C. Ammeter	
(1) Normal	
(2) Fast	
D. Ohmmeter	
(1) Normal	
(2) Guarded	
(3) External Voltage	
E. Battery Check	
F. Using External Indicators	
G. Miscellaneous Applications	
(1) Current Integrator	
(2) Current Source	
(3) Static Charge Detector	
ACCESSORIES	V
MAINTENANCE	VI
A. Trouble Shooting	
B. Schematic	
C. Voltage-Resistance Diagram	
D. Replacement Parts List	

571 & 572
INSTRUMENT POOL
LIBRARY
IH 2C-224

SECTION I INTRODUCTION

The Keithley Model 600 Electrometer is an ultra-high impedance voltmeter with full-scale ranges of 0.01, 0.03, 0.10, 0.30, 1.0, 3.0 and 10 volts. Accuracy is within 2% of full scale on all ranges.

The maximum input resistance is gr ater than 10^{14} ohms; in addition, the input resistance may be varied in decade steps from one ohm to 10^{11} ohms by means of the shunt resistors built into the instrument. Thus, the 600 is not only appropriate for measurement in high-impedance circuits, but also can be used where a high input impedance would merely introduce unwanted pickup.

The 600 may be used as a direct-reading ammeter from 3 amperes to 10^{-13} ampere full scale. This 14-decade range is covered in overlapping 3x and 10x scales. Accuracy is within 3% of full scale from 3 amperes to 10^{-10} ampere, and 4% of full scale from 3×10^{-11} to 10^{-13} ampere.

Two current measuring methods are available to the user of the 600. They are selected by a slide switch at the back of the instrument. Normally, current is determined by measuring the voltage drop across a resistor shunted from input to ground. Alternately, on the 10^{-7} to 10^{-13} ampere ranges, negative feedback can be applied to the input of the voltmeter through the current measuring resistor. This largely eliminates the input drop and increases measuring speed, particularly on the more sensitive ranges.

The 600 measures 200 ohms to 10^{11} ohms with a two-terminal input. With a guarded input, its range is extended to 10^{13} ohms. Unlike conventional ohmmeters, information is presented on the linear scales used for current and voltage readings. Accuracy is within 4% of full scale up to 10^{9} ohm, within 6% beyond.

As a dc preamplifier, the 600 has a maximum gain of 100, obtainable in 7 steps of 0.1, 0.3, 1, 3, 10, 30 and 100. Gain accuracy is within 2% on all gain steps. The continuing stability of the gain is assured by a feedback factor in excess of 100 on any range.

The output is minus 1 volt, open circuit, with an internal resistance of 17K. Thus, the output may be used for driving oscilloscopes or pen recorder amplifiers, or the output may be shunted down to provide 10- or 50-mv outputs for servo-rebalance recorders. Maximum current output is 60 microamperes into a short circuit. Shorting the output does not affect meter accuracy.

SECTION II SPECIFICATIONS AND DESCRIPTION

SPECIFICATIONS

Ranges:

(a) Voltage: 0.01, 0.03, 0.1, 0.3, 1, 3, and 10 volts full scale
(b) Current: 3 amperes to 10^{-13} amperes full scale in 1x and 3x overlapping ranges
(c) Ohms: 10^{4} ohms to 10^{13} ohms full scale on linear 1x and 3x overlapping ranges.

Accuracy:

(a) Voltage: 2% of full scale on all ranges
(b) Current: 3% of full scale from 3 amperes to 10^{-10} amperes. 4% of full scale from 3×10^{-11} to 10^{-13} amperes.
(c) Ohms: 4% of full scale from 10^{4} ohms to 10^{9} ohms. 6% of full scale from 3×10^{9} ohms to 10^{14} ohms.

Resistance Standards:

1, 10, 100, 1000, 10^{4}, 10^{5}, 10^{6}, 10^{7}, 10^{8}, ohms 1% accuracy; 10^{9}, 10^{10}, and 10^{11} ohms, 2% accuracy. The 10^{9}, 10^{10} and 10^{11} ohm resistors may be expected to change slightly in value with age.

Input Impedance:

On the VOLTS position, the input impedance is greater than 10^{14} ohms resistive, shunted by approximately 30 micromicrofarads.

Drift:

Less than 2 millivolts per hour after a 30 minute warm-up.

Recorder Output:

Minus one volt for full scale meter deflection, with 17K source impedance.

Amplifier:

Frequency response is DC to 100 cycles on the most sensitive range, rising to 1KC on the least sensitive range. Maximum gain is 100. Noise is less than 3% (peak to peak) of full scale.

ALS: The input connector is Amphenol 83-79S. ... post which plugs into the center of the con- ... A ground binding post is mounted on the panel ...

... switch, located ... the ... r. This control ... the AMPERES position, a ... ciprocal of the designat... input resistance as well ...

... SCALE ..., located ... determines the v... sets the voltage ... OHMS or AMPERES, ... OHMS or AMPERES ...

... located in ...

... determ... batteries.

... the ... input terminal ... is shorted.

... connection by a recessed ...

... This control ... current measurement ... FAST position ... around the ... control. In ... the ... is ... used when the ... repeated by ...

... imped... of the ... when it is ... a ...

... If the ... is quite badly ... the ... is used ... to range.

The Keithley Model 600 is a battery operated multipurpose dc measuring instrument of extremely wide range. The measuring ranges are summarized below:

10 millivolts to 10 volts full scale. The input impedance is greater than 10^{14} ohms shunted by approximately 30 microfarads on the VOLTS position of the FUNCTION switch. The input resistance may be varied from 10^{14} ohms to 1 ohm in decade steps by rotating the function switch in the AMPERES range positions.

VOLTAGE WITH ACCESSORIES: The Model 6102 10:1 divider probe extends the measuring range to 100 volts. The divider resistance is 10^{10} ohms and its division accuracy is 1%.

The Model [illegible] divider probe extends the measuring range to 10 KV. Its input resistance is 10^{12} ohms and its division accuracy is 3%.

CURRENT: [illegible] to 3×10^{-1} amperes the current is measured by measuring the drop across a resistor shunted across the input. From 10^{-7} to 10^{-13} [illegible] switch on the back panel in the FAST position, negative feedback is applied around the shunt resistor. This makes the input drop negligible and improves speed of response considerably on the low current ranges.

[illegible]

The linear ohms scale is achieved by measuring the unknown resistor with a known, constant current flowing through it. The voltage drop across the sample is then proportional to the resistance. Resistance from 10^{4} ohms to 10^{11} ohms full scale is measured by a two terminal method. From 10^{11} to 10^{13} ohms, use of the GUARD terminal available on the rear of the instrument is recommended.

AMPLIFIER: The frequency response of the Model 600 as an amplifier is flat from dc to 100 cycles on the 10 millivolt range rising to 1KC on the 10 volt range. The output is 1 volt for full scale meter deflection. In the NORMAL micro-microammeter position, one side of the output is grounded; on the FAST micro-microammeter position the output is floated. For directions pertaining to the use of recorders see Section IV-F.

SECTION III CIRCUIT DISCUSSION

The basic element of the Model 600 is a highly accurate, stable dc voltmeter with a full scale sensitivity of 10 millivolts and an input impedance greater than 10^{14} ohms shunted by 30 micro-microfarads. Amperes and ohms are measured by the use of resistance standards. The various connections necessary for ampere and ohms measurements will be discussed following the detailed description of the amplifier.

A. VOLTMETER

Refer to DR-12014C at the rear of the manual.

The amplifier proper consists of V1, V2 and V3. V4 is a cathode follower which drives the amplifier at the same instantaneous potential as the input signal. In other words the neutral or ground terminal of the amplifier is not grounded to the chassis but is attached to the output cathode follower. Fig. 600-1 shows this diagramatically. The amplifier A is driven by the cathode follower.

The purpose of this arrangement is to allow the input to accept relatively large input voltages without use of input dividers, which are neither stable nor accurate at high impedance. Consequently, the Model 600 will accept 10 volts without the use of input dividers, preserving the high input impedance and accuracy of the amplifier. Accessory probes are available for extending the voltage range at reduced input resistance and accuracy.

Since the amplifier proper is driven by the cathode follower, the plus and minus 30 volt supplies for the cathode follower are referred to input ground while the battery supplies for the amplifier are referred to amplifier ground which is "floating". In subsequent discussion, reference will be made to the amplifier ground as "floating ground" and to cathode follower ground as "output ground".

The amplifier input consists of two balanced 5886 electrometer tubes. The filaments are operated in parallel from battery B1. The control grid of V1, the active electrometer tube, is protected by R2, a 10^9 resistor, bypassed for high frequencies by C2. The control grid of V2, the "dummy" tube, is returned through a variable voltage to floating ground. This variable supply is made up from B2a, B2b, R15 (ZERO on the front panel) and R11, R28, R29, R30, R31, R32 on SW-4 (COARSE ZERO on rear panel).

The ZERO controls function by adjusting the dc voltage of the dummy electrometer tube grid.

The voltmeter sensitivity is determined by the resistor placed in series with the meter, R33 through R39. Meter current passing through R42 develops the constant one volt output for any range.

C3 and R6 serve to stabilize the feedback loop against oscillation.

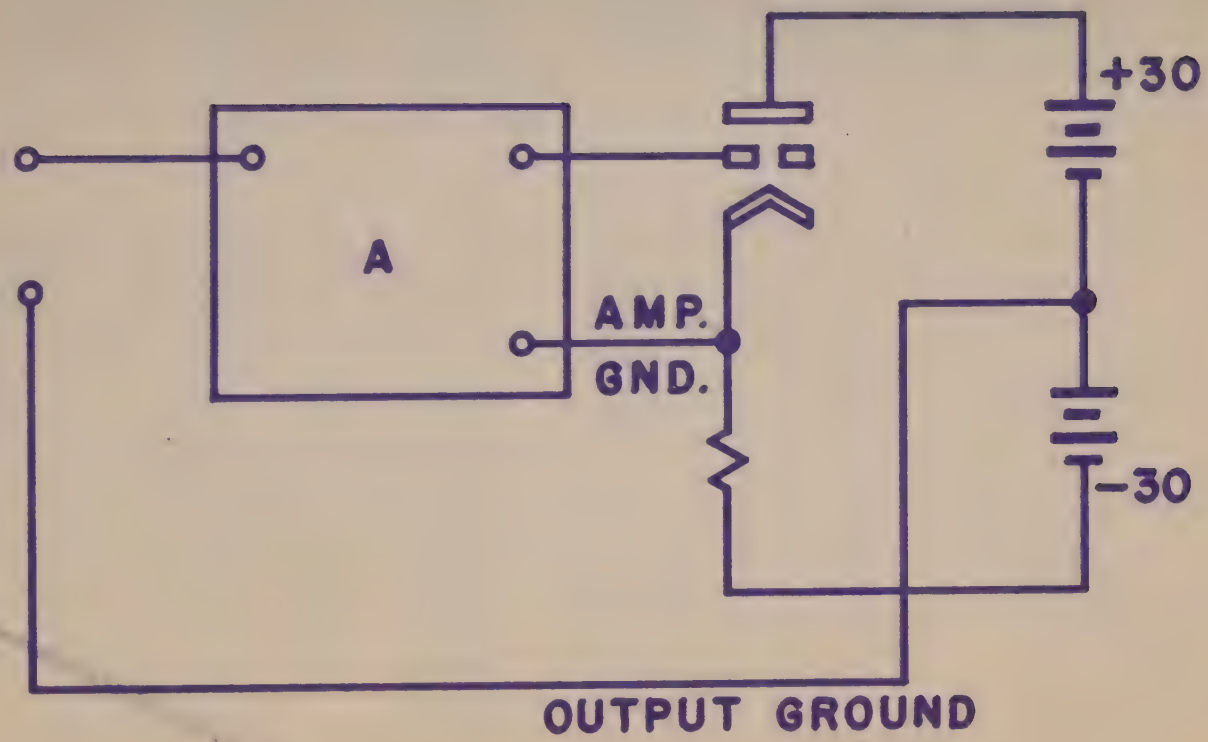


FIGURE 600-1

B. AMMETER

Grid current of the input electrometer tube fixes the minimum current that may be measured. The Model 600 grid current will usually be less than 2×10^{-14} amperes. On low current ranges, the grid current will be apparent and may be balanced out with the ZERO control or subtracted from the final reading.

(1) Shunt Resistor Method (NORMAL)

In the normal operating connection as shown in Fig. 600-2, current is measured by placing a resistor across the input terminals and measuring the voltage drop. Currents from 3 amperes to 10^{-13} amperes may be measured by this method since the range switch selects resistors ranging from one ohm to 10^{11} ohms in decade steps. The voltage drop is selected by the VOLTS switch; the setting is the input voltage drop for full-scale meter deflection.

(2) Feedback Method (FAST)

In the voltmeter discussion above, floating ground has been driven by the cathode follower and output ground has been connected to the low impedance side of the input connector. In the FAST connection, shown in Fig 600-3, the amplifier ground is connected to the low impedance side of the input; the cathode follower ground floats, and negative feedback is applied through the shunt resistor.

In the Model 600, it is possible to use this connection with currents of 0.1 microamperes or less. To change the connection, remove the lock from the NORMAL-FAST switch at the bottom of the rear panel and change it to the FAST position. The advantages of this connection are:

(a) The effect of input capacity is largely neutralized, that is, the time constant of the input and cable capacity and the shunt resistor used will be decreased at least 100 times as compared to the NORMAL connection, corresponding to a 100-fold increase in response speed.

(b) The input drop will be reduced about 100 times.

If Fig. 600-3 is again consulted, it will be seen that this connection converts the 600 into an operational amplifier with a resistor from the output to the input. Therefore, the following cautions apply:

(a) The input cannot be shorted since this will remove the feedback.

(b) The internal impedance of the current source being measured should not be less than about one-tenth of the value of the feedback resistor used for measurement.

(c) This connection should not be used for measuring the leakage current of capacitors since the connection of a capacitor to the input causes the circuit to be transformed into a differentiator with the resultant extreme sensitivity to very small voltage transients. For this measurement the NORMAL should be used.

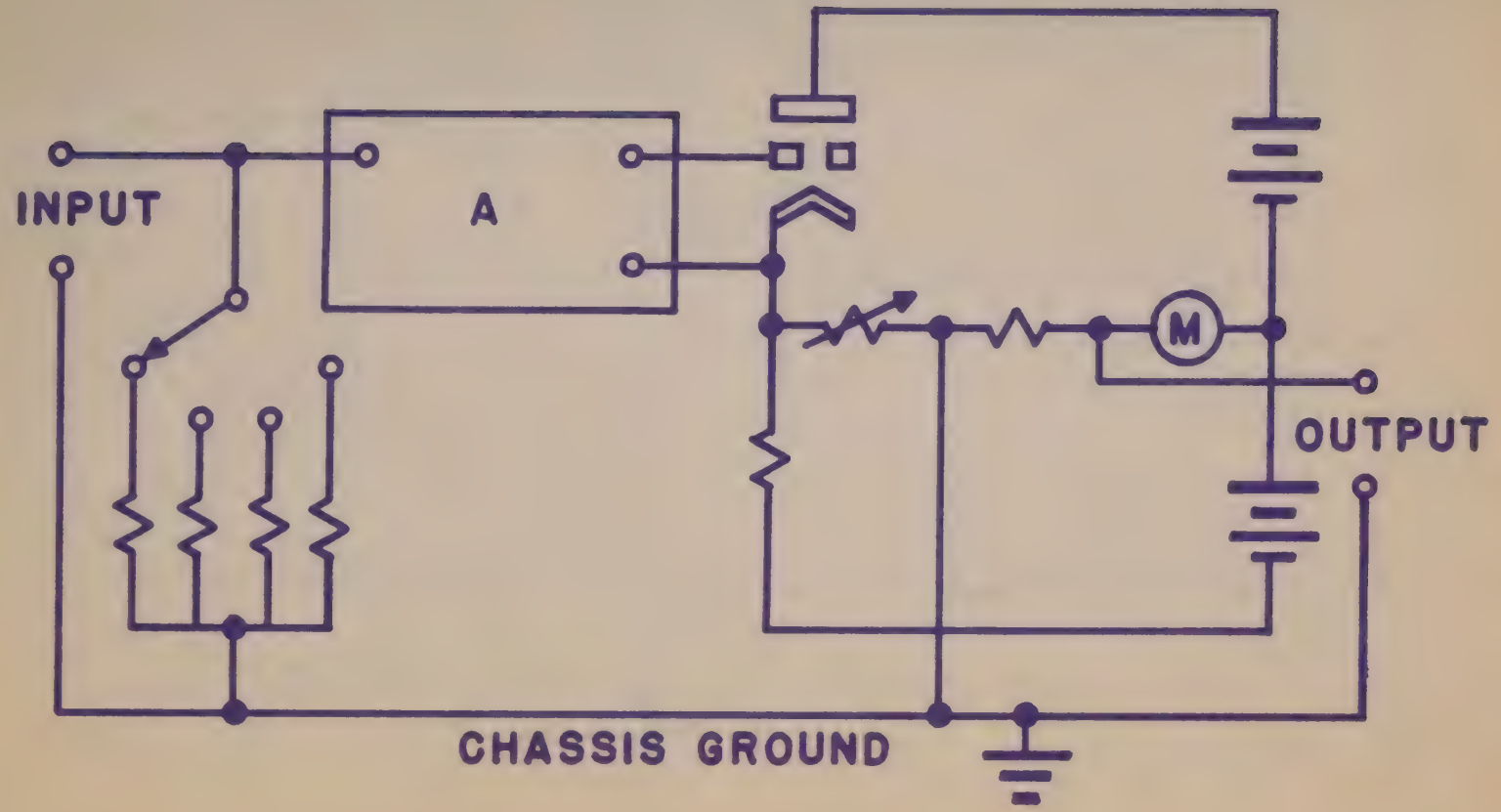


FIGURE 600-2

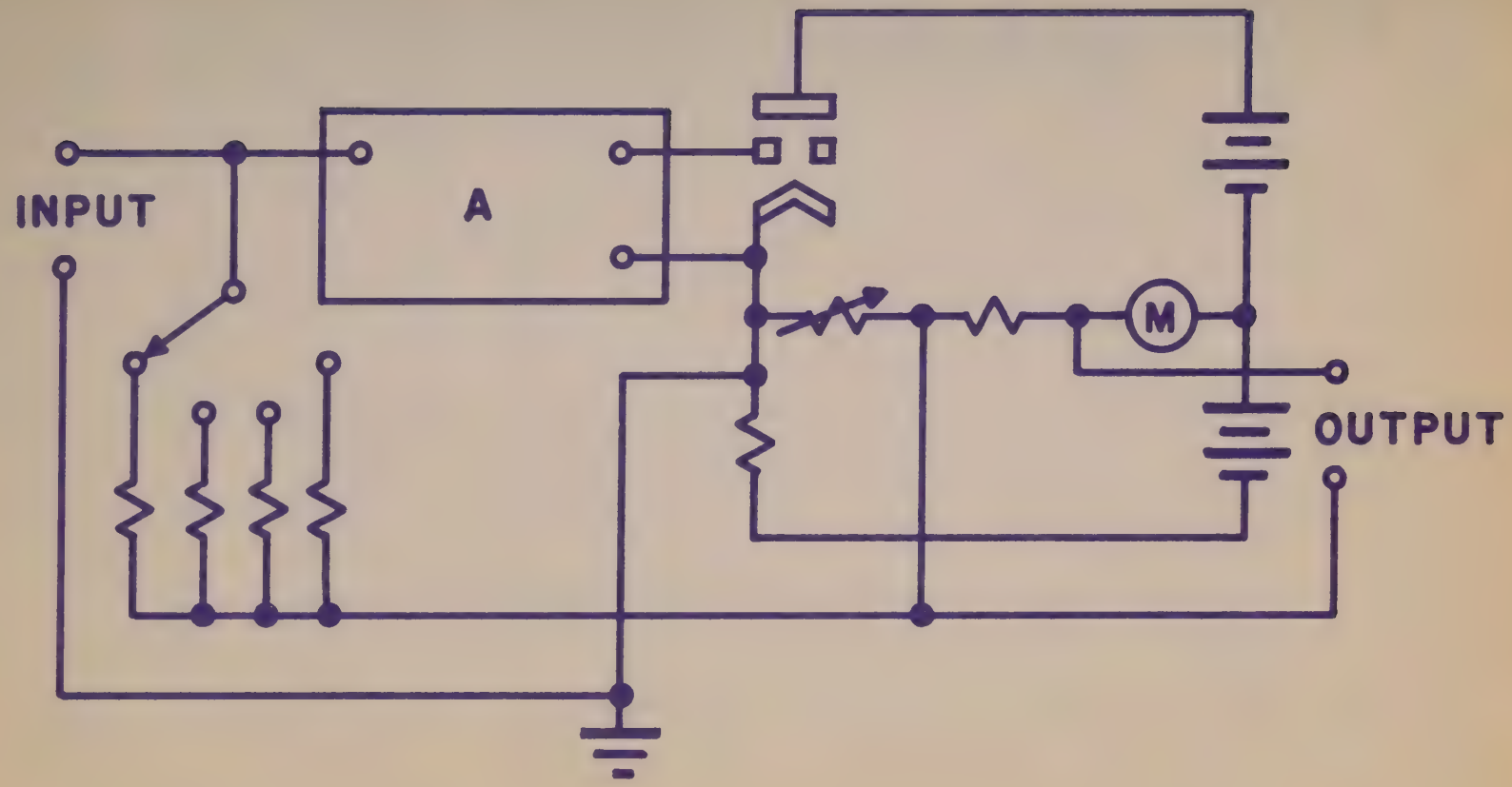


FIGURE 600-3

(d) Do not attempt to use the FAST connection for currents exceeding 0.1 microamperes.

OHMMETER

(1) Two Terminal Method

The model 610 employs a linear scale to provide a voltmeter of high accuracy. The linear ohms scale is obtained by supplying a constant current to the sample and measuring the voltage drop across it. The method is shown in Fig. 600-4.

(2) Ohms measurement using GUARD terminal:

There are two disadvantages with the method just outlined:

(a) When measuring resistances greater than 10^{11} ohms, input capacity causes the meter reading to be annoyingly slow.

(b) If it is desired to use large voltages across the sample, this same voltage will appear across the input insulation of the electrometer and the input insulation will contribute error to the reading because of the current also flowing in it.

For these reasons a method suitable for measuring ohms is provided.

The switch at the rear of the instrument is moved from NORMAL to FAST and the low impedance end of the resistance sample is connected to the GUARD terminal. Fig. 600-5 shows the arrangement. Now, as with measuring amperes with the FAST method, the amplifier ground is attached to the input ground and the entire voltmeter ground is floating. The result is that feedback is applied through the electrometer to reduce the slowing effect of instrument input capacity. Also, since the potential across the input terminal is small, the leakage error is reduced.

(3) Use of External Voltage Supply

With the constant current method of measuring resistance, the voltage across the unknown may not be arbitrarily selected, and the time of measuring capacitor leakage tends to be long, since constant-current charging is slower than the exponential charge available with an RC circuit.

Due to these facts, it may be desirable to use an external voltage supply and measure the leakage current on the AMPERES scale (NORMAL operation).

The unknown is connected between the input terminal of the electrometer and the source of voltage. This is shown in Fig. 600-6. If the applied voltage is large compared to the voltage drop across the electrometer (so that the voltage across the sample is substantially the applied voltage) the resistance is simply equal to the voltage applied divided by the current measured. If the voltage drop

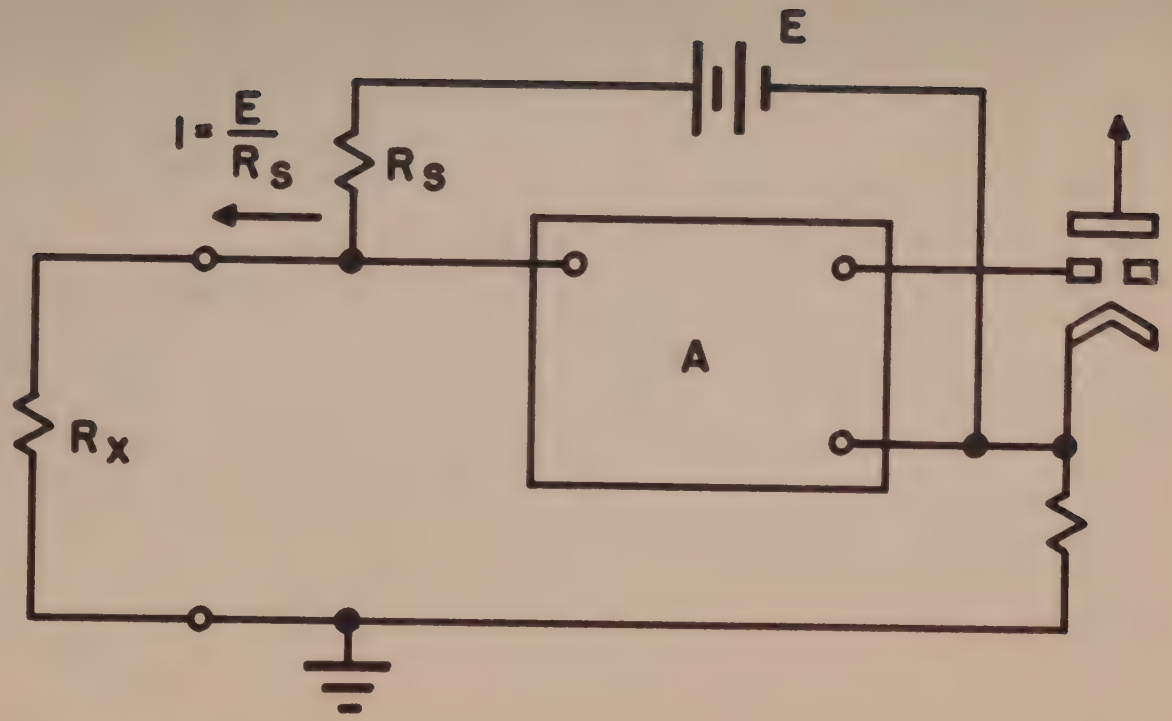


FIGURE 600-4

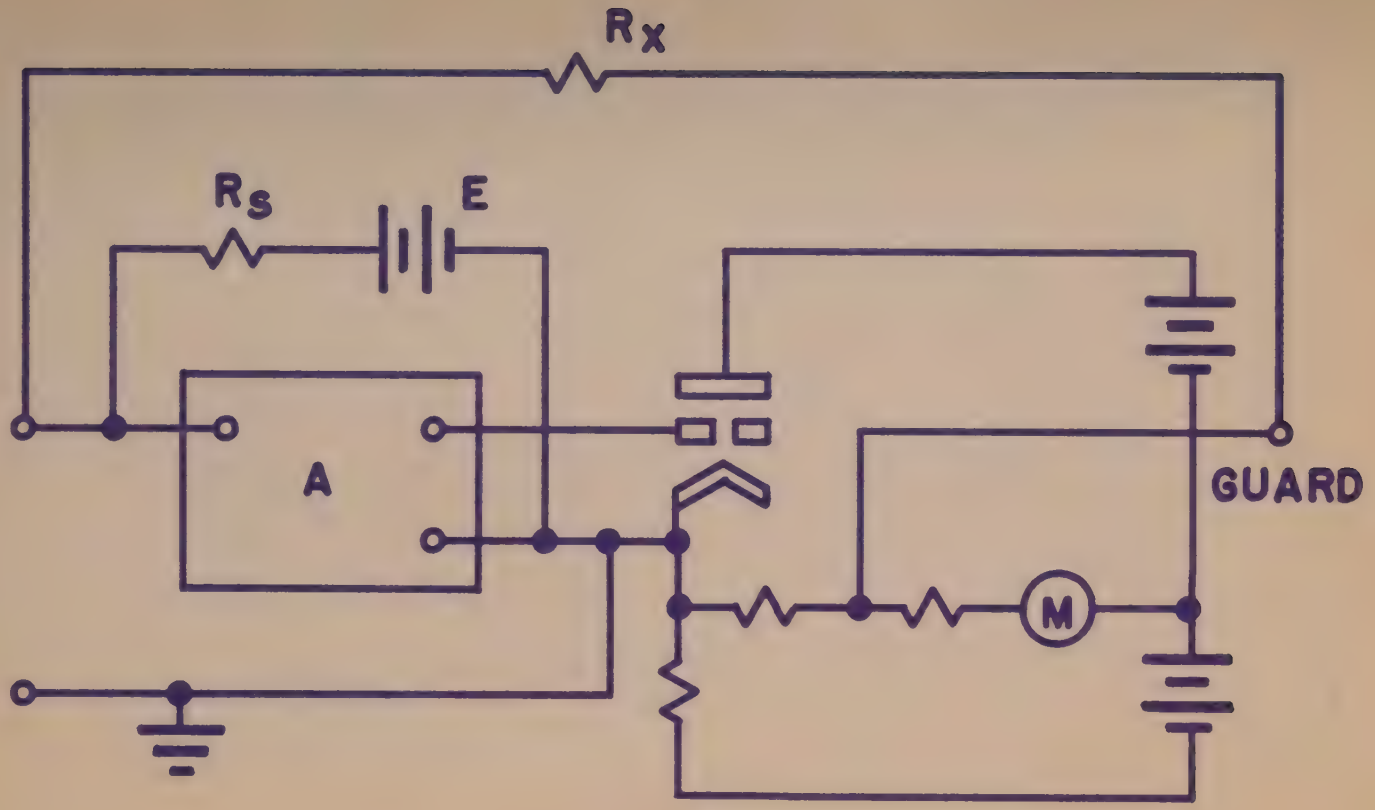


FIGURE 600-5

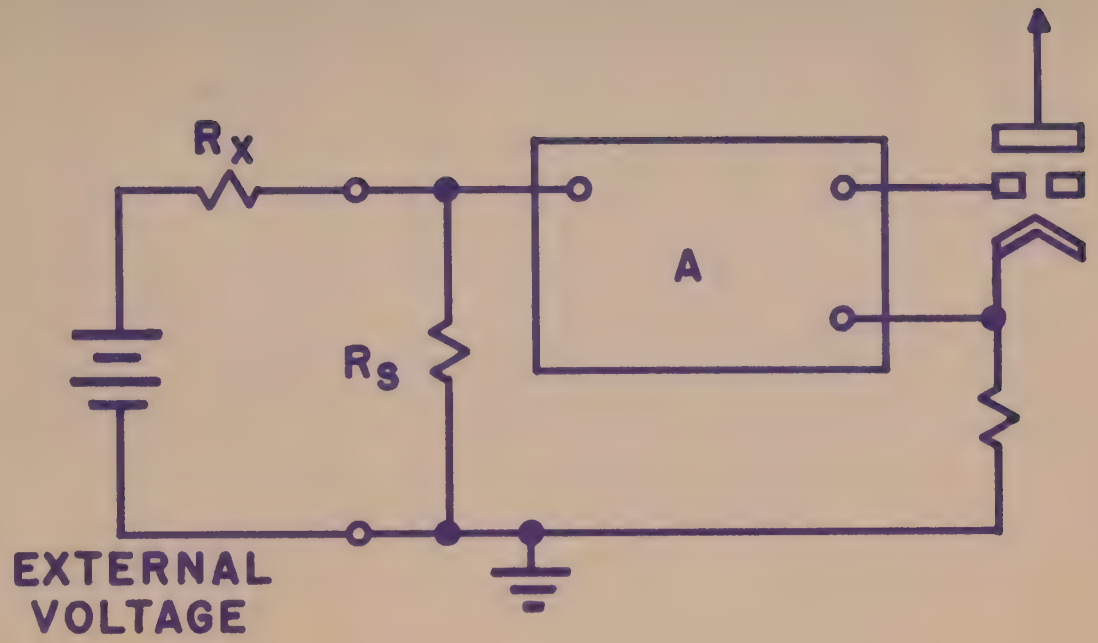


FIGURE 600-6

A. PREPARING THE INSTRUMENT FOR OPERATION

(1) Set controls as follows:

VOLTS SWITCH: 10 volts.

FUNCTION SWITCH: VOLTS

ZERO CHECK SWITCH: Locked

INPUT TERMINAL: Shield with cap

(2) Turn the METER switch to meter +. The instrument should come to zero in approximately 5 seconds.

(3) Rotate the VOLTS switch toward the high sensitivity end, adjusting ZERO as required. If it is impossible to zero the meter with the front panel ZERO control, use COARSE ZERO control on rear panel to bring the instrument within range of the ZERO control.

(4) Connect leads as required for measurement. If high impedance is involved, the input should be shielded using a coaxial connection or shielded enclosure. The various accessories for the MODEL 600 may be used.

If the impedance is low (below about 10^{10} ohms) and leads can be kept short, the binding post adapter furnished with the instrument may be used.

The Keithley Model 6101 Shielded Test Probe will suffice for most measurements.

B. MEASURING VOLTAGE

Place FUNCTION switch at VOLTS. Turn VOLTS switch to expected sensitivity and check meter zero. Release ZERO check, and read. If the sensitivity of the instrument is increased, recheck the zero reading.

For voltages greater than 10 volts, use the Model 6102-10:1 Divider Probe, or the Model 6103-1000:1 Divider Probe and measure as above.

C. MEASURING CURRENT

(1) NORMAL method (3 amperes to 10^{-13} amperes full scale).

Turn FUNCTION switch to desired OHMS range. Make sure that NORMAL FAST switch is in the NORMAL position.

Connect resistance sample to be measured only after ZERO CHECK switch has been locked. The test voltage will be the value read on the meter scale multiplied by the setting of the OHMS-AMPS MULTIPLIER.

E. BATTERY CHECK

Turn METER switch to B1, B2, etc. A.1 batteries should read [illegible] scale or higher on the meter.

[illegible] B4, and B5 are tested directly. B2a and B2b are tested in series on position B2. Since the battery drains are nearly identical in B2a and B2b, both should be changed when the series measurement reads low.

[illegible] B7 are not tested because they are operated under virtually [illegible] life conditions. They may be replaced yearly as a measure of preventive maintenance or may be tested at any time by removing the case and measuring with a voltmeter. They should be replaced if they test less than eight volts.

F. USING EXTERNAL INDICATORS

[illegible] recorders as well as high impedance devices such as oscilloscopes and pen drive amplifiers.

(1) For use with servo rebalance recorders:

The output circuit consists of a 16.67K resistor through which 60 microamperes flow for full scale deflection of the panel meter. Shorting the output does not affect the meter reading of the Model 600, but low impedances placed across the output terminals lower the terminal voltage for full scale deflection. Thus, if it is desired that the output voltage for full scale be 10 millivolts, a [illegible]83 ohm resistor should be connected across the output terminals. If a full scale of 50 millivolts is required, 278 ohms should be used.

(2) For use with oscilloscopes and pen recorder amplifiers, the output is minus one volt for full scale meter deflection on any range.

The frequency response is dc to 100 cycles on the 10 millivolt range rising to 1 kc on the 10 volt range. The maximum amplitude which can be delivered by the amplifier without distortion is [illegible] volts peak to peak.

G. MISCELLANEOUS APPLICATIONS

CURRENT INTEGRATING: The Model 600 may be used to integrate [illegible] for small currents such as ionization chamber or electrometer currents. Since it is desirable to operate the electrometer input above the [illegible] portion of the [illegible] planned to use this region.

To integrate currents, connect a polystyrene capacitor of suitable value between the input terminal and the input. The FUNCTION switch is set to [illegible] so that there is no resistance placed across the capacitor. Then if Fig. 600-1 is consulted, it can be seen that

replace[illegible] capacitor and the
The charge [illegible]or in coulombs
[illegible] capacitance [illegible] (in farads) and
[illegible]LL SCALE [illegible]s). If it i
[illegible]t be intr[illegible] integratin
[illegible]nt resist[illegible]ted by the act

[illegible]ed that th[illegible] enclosed in
[illegible]ion to the [illegible] may be mad[illegible]y
[illegible]. The conne[illegible]ut termina
a coaxial [illegible] one side of
[illegible]t input is [illegible] side of [illegible]e

[illegible] is suggested [illegible] ZERO CHECK [illegible]to
[illegible]for the ca[illegible]rting the i
[illegible]lease the [illegible]itch. If t
[illegible]ge over a [illegible] time it is
[illegible]nt be use[illegible]lt range or [illegible]gh
[illegible]d current[illegible]tors.

SOURCE: [illegible]ring ohms [illegible]t is design[illegible] to
[illegible]to any devi[illegible]ss its inpu
[illegible]gnitude of the cur[illegible] to the recip[illegible]al
[illegible] OHMS segme[illegible]ion switch. [illegible]he
[illegible] used as a [illegible] for calibr[illegible]on
[illegible]sired.

[illegible]UNCTION [illegible] The curre[illegible]t
[illegible] is the rec[illegible] OHMS setti[illegible]an
[illegible]ting of th[illegible]ALE switch. [illegible]ow
[illegible]e accurate [illegible] should be [illegible]
[illegible]nt to b[illegible]ifier on th[illegible]
[illegible]itch.

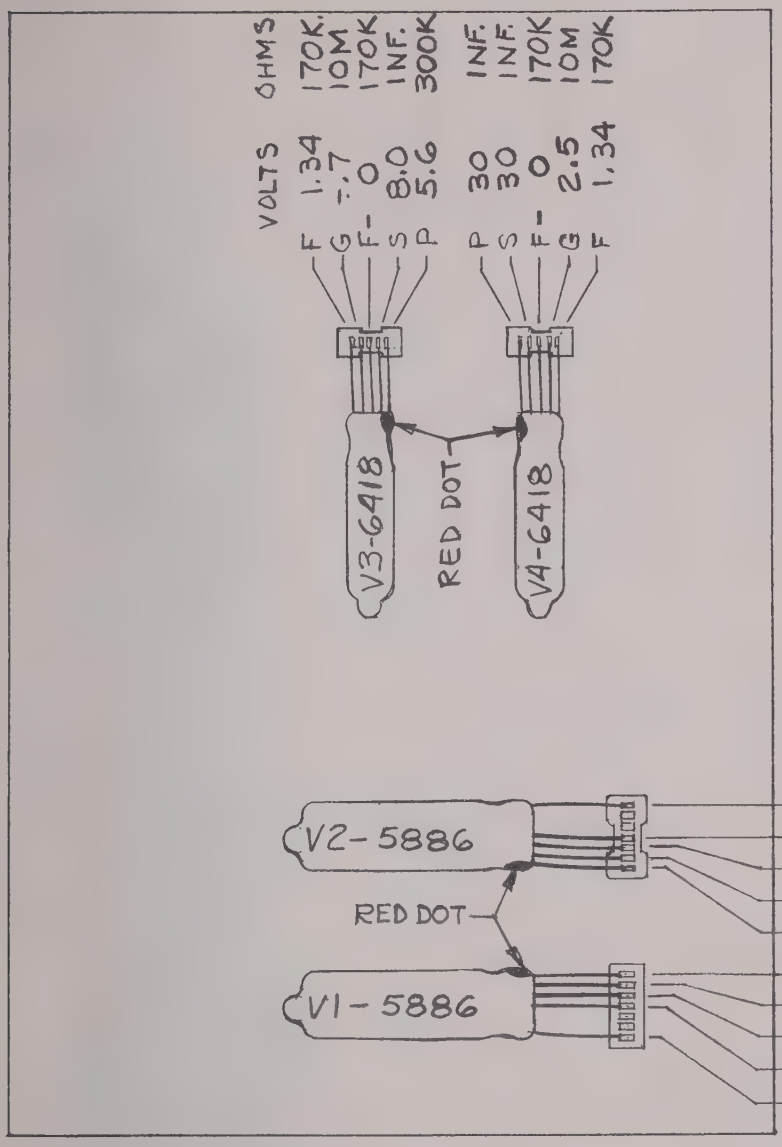
[illegible]: The ins[illegible]ed and the [illegible]CT
[illegible]he voltage [illegible] perhaps pl[illegible]d
[illegible]le. The [illegible]s then bro[illegible]
[illegible] input connec[illegible] [illegible]00. Depend[illegible] on the
[illegible]e and the [illegible] voltage will [illegible] induced
[illegible] can be rea[illegible] meter. The [illegible]strument
[illegible]quently si[illegible]n of charg[illegible]o
[illegible]rid current [illegible] drift of [illegible] voltag

[illegible] across the inpu[illegible] drift due
[illegible]nsitivity to charge. [illegible] electrode con[illegible]
[illegible]ich increas[illegible]ce between
[illegible] object will [illegible] the [illegible]nsitivity

	escription	
	[illegible] mercury. [illegible]	[illegible]
	[illegible] mercury, [illegible]	[illegible]
	[illegible]	
	[illegible]	
	[illegible]	[illegible]
	[illegible]	
	[illegible]	
	[illegible]	
	[illegible]	[illegible]
	[illegible]	
	[illegible]	[illegible]
	[illegible]	[illegible]
	[illegible]	[illegible]

Battery, mercury 1.35v, 1 :) (SH	
Battery, mercury 8.04v, 6.6 Ma-h	
Same as B2	
Same as B1	
Battery, layer dry cell, 30v	
Same as B4	
Same as B2	
Same as B2	
Capacitor, ceramic disc, 100 mmf, 600v	C22-100
Same as C1	
Capacitor, ceramic disc, .01 mfd, 600v	C22-.01
Capacitor, ceramic disc, .02 mfd, 600v	C22-.02
Meter, 50 microampere, dial 430-1326	ME-12
Resistor, composition, $\frac{1}{2}$w, 10%, 1 meg	R1-1M
Resistor, composition, $\frac{1}{2}$w, 20%, 10^9 ohms	R37-10^9
Resistor, deposited carbon, 1w, 1%, 10 meg	R13-10M
Resistor, composition, $\frac{1}{2}$w, 10%, 4700	R1-4700
Same as R5	
Resistor, deposited carbon, $\frac{1}{2}$w, 1%, 312K	R12-312K
Resistor, deposited carbon, $\frac{1}{2}$w, 1%, 220K	R12-220K
Resistor, deposited carbon, $\frac{1}{2}$w, 1%, 450K	R12-450K
Resistor, deposited carbon, $\frac{1}{2}$w, 1%, 3400	R12-3400
Resistor, deposited carbon, $\frac{1}{2}$w, 1%, 9K	R12-9K
[illegible]	[illegible]
Potentiometer, 10 turn, 5% 10K	RP4-10K
Resistor, wirewound, 10w, 1%, 1 ohm	R34-1

DR 12124 -A



CHANGES	

THE ABOVE VOLTAGE AND RESISTANCE READINGS WERE TAKEN WITH CONTROLS SET AS FOLLOWS;

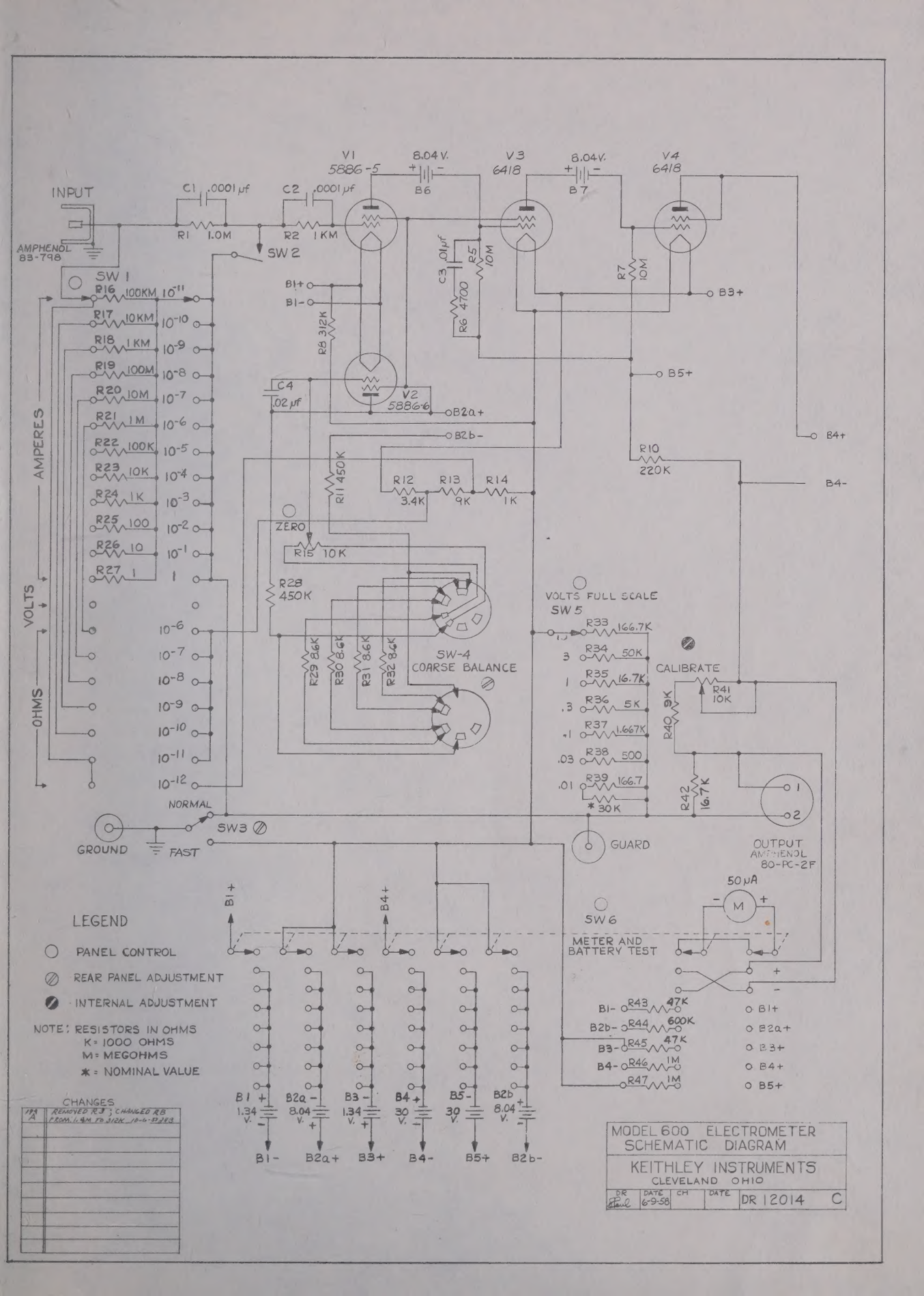
VOLT SWITCH ON 10
METER SWITCH ON METER +
RANGE SWITCH ON VOLTS
ZERO CHECK LOCKED
OUTPUT AT ZERO
FAST-NORMAL SWITCH IN NORMAL POSITION

RESISTANCES ARE APPROXIMATE, READINGS TAKEN WITH VTVM TO GROUND.

MODEL 600 ELECTROMETER
VOLTAGE - RESISTANCE DIAGRAM

KEITHLEY INSTRUMENTS
CLEVELAND, OHIO

DR	DATE	CH	DATE	DR 12124 -A
[illegible]	8-11-58			



LEGEND

- ○ PANEL CONTROL
- ⊘ REAR PANEL ADJUSTMENT
- ◐ INTERNAL ADJUSTMENT

NOTE: RESISTORS IN OHMS
K = 1000 OHMS
M = MEGOHMS
✱ = NOMINAL VALUE

CHANGES

ITR A	REMOVED R3; CHANGED R8 FROM 1.4M TO 312K 10-6-59 JHS

MODEL 600 ELECTROMETER SCHEMATIC DIAGRAM

KEITHLEY INSTRUMENTS
CLEVELAND OHIO

DR	DATE	CH	DATE	DR 12014	C
Paul	6-9-58				

545
Amfille
WHITE